Two-Hand Virtual Object Manipulation Based on Networked Architecture

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Abstract. A setup for bimanual virtual object manipulation is described in this paper. Index and thumb fingers are inserted in the corresponding thimbles in order to perform virtual object manipulations. A gimble, with 3-rotational degrees of freedom, connects each thimble to the corresponding serial-parallel mechanical structure with 3 actuated DoF. As a result, each finger has 6 DoF, movements and forces can be reflected in any direction without any torque component. Scenarios for virtual manipulation are based on distributed architecture where each finger device has its own real-time controller. A computer receives the status of each finger and runs a simulation with the virtual object manipulation. The information of the Scenario is updated at a rate of 200 Hz. The information from the haptic controller is processed at 1 kHz; it provides a good realism for object manipulation.

Keywords: Haptic devices, bimanual manipulation, multifinger devices, collaborative manipulation.

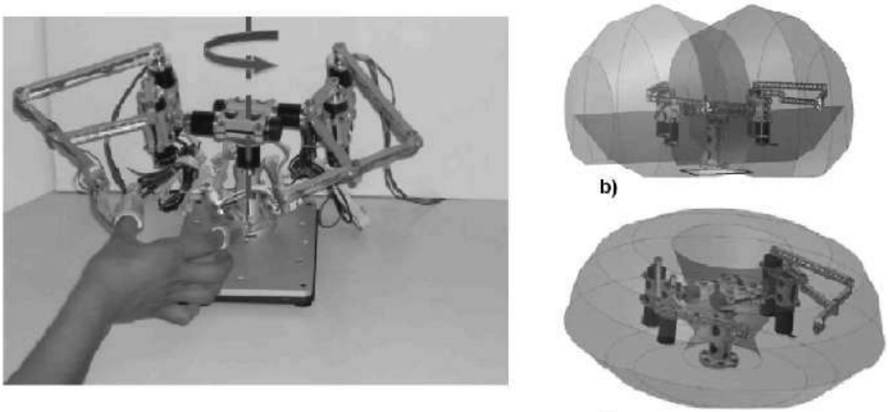
1 Introduction

The use of multi-finger haptic devices provides a higher realism in object manipulation; it also recreates virtual object interaction in a more natural and easy manner. A great step forward in virtual object manipulation has been achieved with only one contact point that simulates palpation or exploration of the virtual object surface. However, at least two contact points per hand are required in advanced manipulation tasks to grasp and properly handle objects. Relevant examples of this advanced manipulation can be found in applications such as telerobotics [1-2] and medical applications [3-4].

In this paper, a haptic interface called MasterFinger-2 (MF-2) [5] has been used for developing a bimanual setup. This setup consists of two MF-2 haptic devices. Workspace and main component of this setup are explained in section 2. Section 3 shows how scenarios are developed for virtual object manipulation considering multiple contact points. An example of a box manipulation is described in section 4 and conclusions are summarized in section 5.

2 Setup Description

The mechanical structure was designed for the MasterFinger-2 haptic interface in order to enable object manipulation within a virtual environment. The setup design is based on a modular design, in which each finger represents a module managed as a haptic device. Fingers have 6 degrees of freedom (DoF) for movement; therefore any position and orientation can be achieved in the workspace. The first 3-DoFs are actuated by three DC motors. These actuators reflect forces in all directions. The last 3-DoFs are passive, these DoF have a gimble configuration. This gimble allows the end-effectors to be oriented towards any direction so as to increase capability of grasping and ease development of automatic tasks. Mechanical structure of both fingers is connected to the MF-2 base by using an additional actuator. This redundant actuator is located on the horizontal plane and provides an extra DoF to the interface, which significantly increases workspace. Fig. 1 shows the designed modular haptic interface and its workspace, redundant axis is in red. Main difference between MF-2 and the use of 2 common haptic devices can be seen in Fig.1.b and Fig.1.c. Fig.1.b represents the connection of 2 haptic devices (one per finger). Fig.1.c represents, however, the workspace of MF-2 where the redundant axis allows to significantly increase the available space for manipulation.

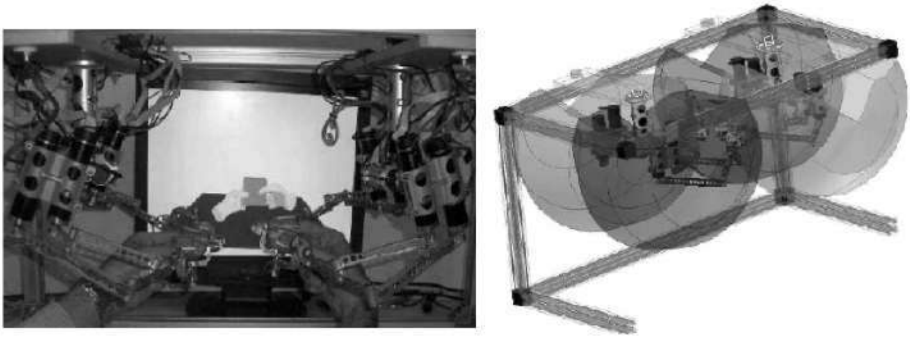


a) b) c)

Fig. 1. MasterFinger-2 (a), it is used by inserting thumb and index in the corresponding thimbles. Workspace of each finger (b); workspace of the MF-2 including the additional DoF that allows rotation in a vertical axis (around the device base).

The bimanual setup is made up of two MasterFinger-2, as shown in Fig 2. According to the task configuration, the haptic interface can be used in its original position as shown in Fig.1, or in an inverted position as shown in Fig.2. The second configuration increases the dexterity to perform manual tasks since the central area is free of collisions among the device parts. In addition, the ability of touching, grasping, or moving an object using both hands increases. It provides users with a more realistic manipulation. The distance between both MF-2 bases varies depending on virtual object size. MF-2 base distance should be above 50 cm., so as to avoid collision between different hand's fingers. the distance between bases in Fig.2.b. is 55 cm., so there aren't collisions between both MF-2.

The volume where fingers are able to move considering this setup is shown in Fig.2.b. This workspace represents the area for free movements. In bimanual manipulation, each finger has to be inside its workspace. It implies several constraints in the area where the virtual object can be manipulated, since distance among fingers has to remain constant. As result, the workspace manipulating a box (as shown in Fig2.a) is significantly reduced regarding the workspace of free movements.



a) b)

Fig. 2. Setup developed for bimanual manipulation (a), user is lifting a box. Workspace depends on the size of the manipulated object. Picture (b) shows the workspace for free movements; when an object is grasped by both hands, new constraints are to be evaluated.

3 Architecture for Scenario Development

The entire system is made up of 2 MF-2, several electronic boards (signal control and power), and software for data processing and scenario simulation. The proper performance of all of these elements implies an architectural design that can properly integrate them. Processing all signals in real time is the main objective of the system and guarantees that haptic devices are stable and the operator perceives adequately the interactive forces with the environment.

A modular and distributed architecture was chosen due to the advantages offered by a system with such characteristics. This design allow simplifying device controllers; it distributes large quantities of processed data, making the simulation faster. Furthermore, it gives the system great flexibility since this open architecture makes the simulation of a large number of applications within multimodal scenarios easier [6]. Each finger is treated as an independent haptic device. This device has its own controller, consisting of a Xilinx Virtex-5 FPGA [7], which closes the control loop of the mechanical device at 1kHz. At each loop step, a reading of the motor encoders and three gimble rotations take place so that finger positions and orientations can be obtained. Additionally, the values of other sensors (thimble contact sensors) are read and the motor electric flows are controlled in order to reflect the manipulation forces. Fig.3 shows the main modules of the architecture.

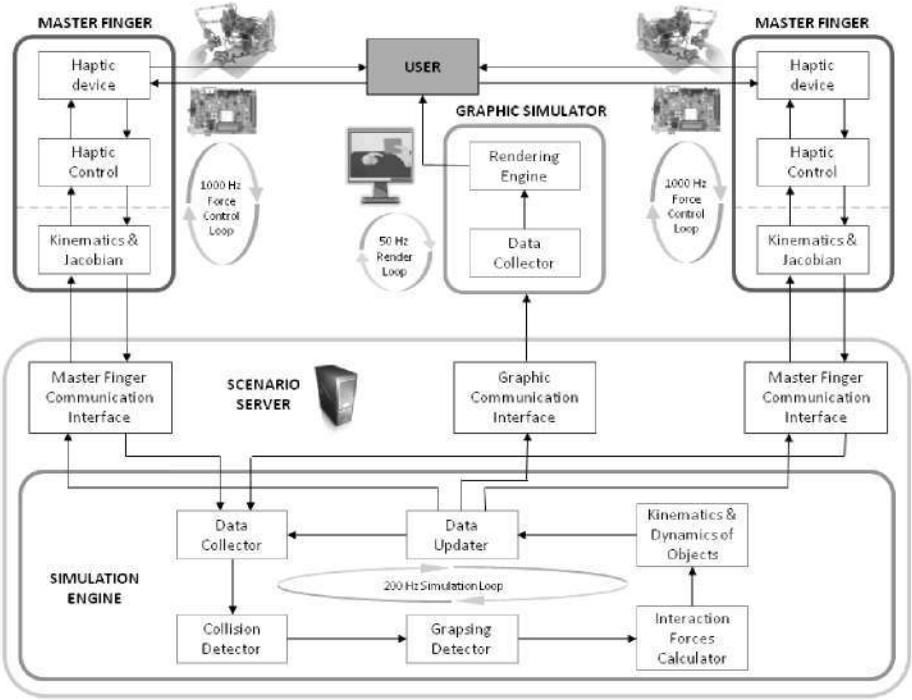


Fig. 3. Diagram of the software architecture required to perform bimanual object manipulation in real time. Each finger has its own controller that acts as a driver. All finger controllers send and received commands and data to the central computer, called scenario server. These data are transmitted via Ethernet.

4 Example of Two Hand Manipulation

The distributed architecture described in Section 3 allows the user to have as many MF-2 as needed thus Simple and complex manipulation tasks can be simulated by using this setup.

The Simulation Engine, integrates a collision detector as shown in Fig.3., this evaluates if two objects are colliding. There are two possible situations when a collision is detected: if both objects are virtual, they will react according to the collision, but if the collision is between the user's finger and a virtual object, the object will react and the MF-2 will exert the user the interaction force based on Hooke's law with dumping.

This collision detector also decides if the user is grabbing the virtual object or if the user is colliding with it.

Most simulations carried out so far focus on analyzing weight discrimination perception difference between grabbing virtual objects using one hand or two hands[8], cooperative tasks done by two users manipulating a common object [9] as shown in Fig.4., and study of trajectories and forces of usual grasping tasks [10].

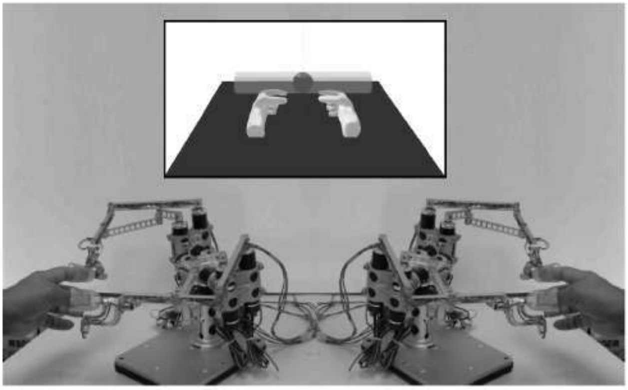


Fig. 4. Two users performing a cooperative task manipulating a cylindrical object, the goal is to cooperate to lift the cylinder and position the sphere in the middle of the cylinder

5 Conclusions

Common haptic interfaces have been used for touching and interacting with virtual environments by applying forces at a single point. More contact points have to be included in order to manipulate virtual objects in a more complex manner. For such purpose, a setup for multifinger haptic interaction has been designed. It allows grasping and manipulating virtual objects by using index and thumb fingers in a wide workspace. This setup proves to be an accurate instrument for manipulating virtual objects. A modular architecture has been implemented in order to run all required processes in real time. This architecture allows developing bimanual manipulation tasks in a more flexible and adaptable manner.

Acknowledgments

This work has been partially funded by the European Commission (IMMERSENCE FP6-IST-027141), and the Spanish *Ministerio de Ciencia e Innovación* (TEMAR, DPI2009-12283) and UPM's Formación de Personal Investigador (RR01/2009).

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